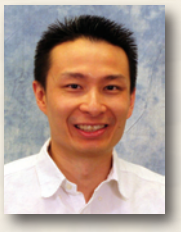
Compact High-Intensity Neutron Source Driven by Pyroelectric Crystals



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A promising technique for identification of unknown threats containing explosives or nuclear material is active interrogation via neutron bombardment and detection of induced gammas or scattered neutrons. A compact, lightweight (<10 lbs), palm-sized, pulseable neutron source or "neutron flare" requiring little electrical power could provide unique capabilities for active interrogation of these threats in the field. Pyroelectric crystals offer a means of achieving such a source by allowing a traditional neutron tube's ~100- to 200-kV power supply, ion source, and accelerator structure to be integrated on a scale an order of magnitude smaller than that of conventional technology. Figure 1 shows a schematic of the first proof-of-principle Crystal Driven Neutron Source (CDNS) experiment, illustrating the pyrofusion principle with a "coupled" ion source and acceleration approach.

Project Goals

Our objective is to establish the scientific basis for a compact palm-size pulseable neutron source driven by pyroelectric crystals using an independent nano-ion source. A primary goal is to achieve the "reversed" configuration illustrated in Fig. 2 after extending results in the coupled configuration. By decoupling the ion source from the pyroelectric crystal providing the acceleration voltage, the neutron source can be pulsed at frequencies and rates required for some interrogation applications, and the accelerating voltages tailored for either the D-D or D-T neutron producing reactions.

To achieve this, we seek a comprehensive understanding and development of pyroelectric HV sources, pyrofusion, and the development of novel nano-ion sources based on carbon nanotubes, gated nanotips, and microgap flashover ion sources. These new compact and high-yield ion sources would also have application for accelerators in general. A successful integrated demonstration with neutron production would complete the basis for the development of a palm-size "neutron flare."

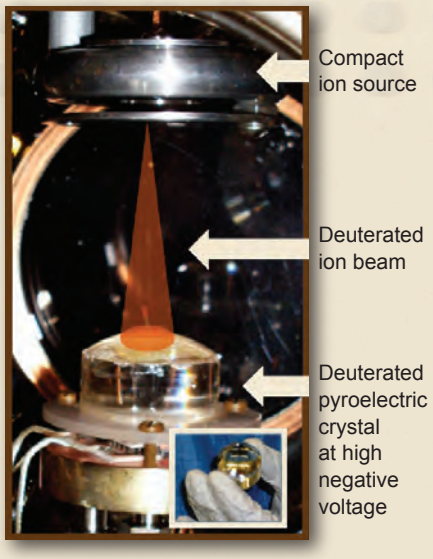

Figure 2. CDNS reversed configuration experiment. The LLNL flashover ion source is shown. The crystal in this case is biased negatively. The inset shows the palm-size scale of the crystal being tested.

Relevance to LLNL Mission

Active neutron interrogation is becoming a key approach for the detection of hidden threats including shielded nuclear materials and explosives. This results from the penetrating nature of fast neutrons and subsequent specificity of the gammas and neutrons produced through inelastic scattering and capture reactions from the target. As such, this technology will have significant impact on applications in homeland security, the military, and intelligence gathering needs. Furthermore, the technology provides new methods of interrogation that are not presently possible due to the nature of existing neutron sources. In this sense, the CDNS represents a new paradigm for active interrogation of threats. This work supports LLNL's national security mission by investigating a new technique that would enable a fundamentally new concept of operations, such as the possibility of a remote probe for covert interrogation.

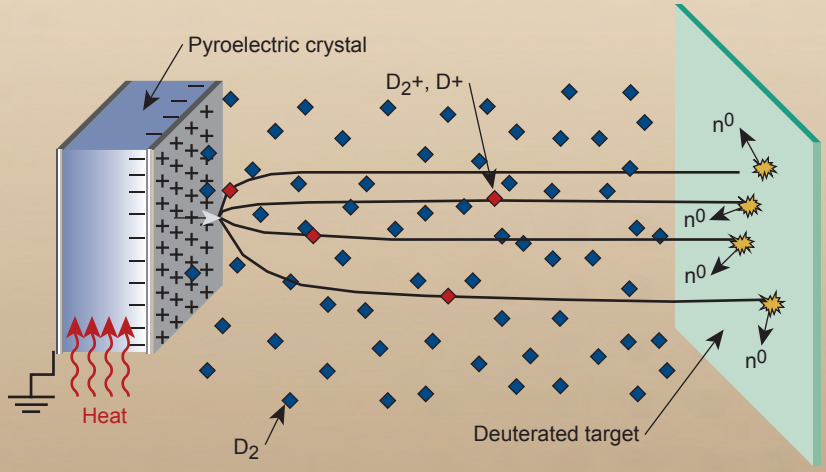

Figure 1. Illustration of pyrofusion effect using a coupled configuration.

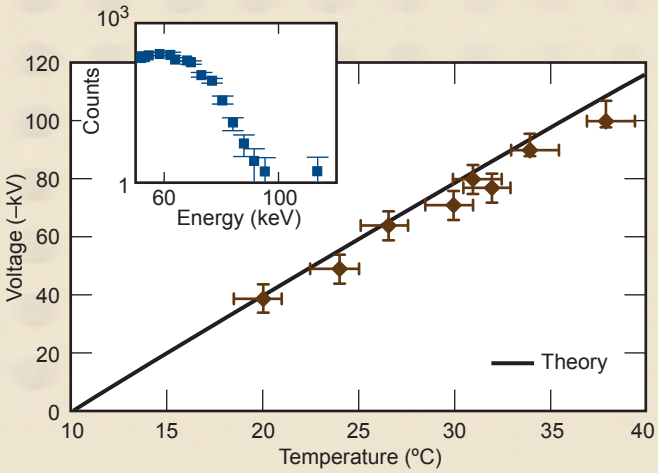

Figure 3. Bremsstrahlung-deduced crystal voltages and predicted voltages from our new pyroelectric model for different temperature cycles starting from 10 °C. The insert shows a sample bremsstrahlung spectrum indicating a crystal voltage of ~95 kV. The slight dip in measured voltages at higher temperatures is due to field emission charge losses not included in the model.

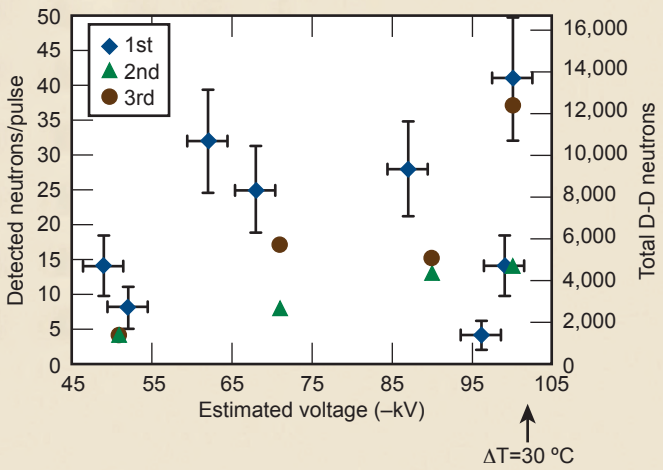

Figure 4. First pulsed pyrofusion neutron data from the CDNS reversed configuration experiment using a 1-cm-thick crystal. LLNL coupled configuration experiments have also demonstrated record D-T equivalent yields up to ~4 x 10^7 neutrons per thermal cycle at a DC rate of ~10^5 D-T equivalent n/s.

FY2009 Accomplishments and Results

We have made important progress on pyrofusion, pyroelectric HV supplies, and the required nano-ion sources for the reversed configuration. For the first time, pulsed pyrofusion via the reversed configuration using a flashover ion source and negative HV deuterated crystal targets was demonstrated. User-controlled yields greater than 10^6 D-T equivalent neutrons were achieved with pulse widths of ~100 ns.

A system model of the crystal and neutron production was constructed and benchmarked for the first time against experiments. Figure 3 illustrates the success of the model in predicting crystal voltages; Fig. 4 documents first pulsed pyrofusion data confirming the viability of the concept.

Concerning ion source development, in addition to the flashover ion source, we successfully fabricated and tested rugged gated nano-tips (Fig. 5) and are currently evaluating their performance for integrated testing in the CDNS.

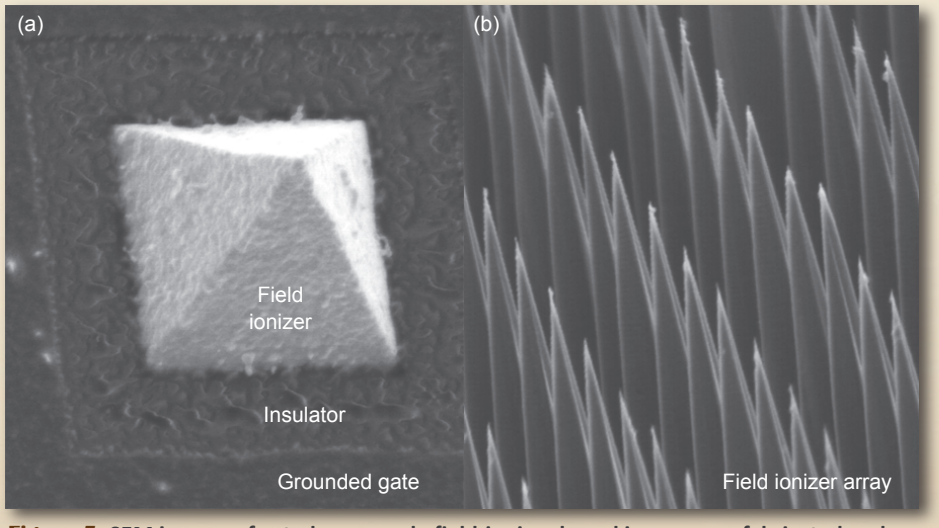

Figure 5. SEM images of gated nano-scale field-ionizer-based ion sources fabricated and studied for the reversed configuration. (a) Each ionizer tip in this ion source has an associated grounded gate. (b) The ionizers in the array for this source are grounded through a mesh suspended above the tips.

Related References

1. Tang, V., G. Meyer, S. Falabella, *et al.*, "Intense Pulsed Neutron Emission from a Pyroelectric Driven Accelerator," *Journal of Applied Physics*, **105**, 2, 026103-1-3, 2009.

2. Tang, V., *et al.*, "Fusion Neutron Science for Energy and National Security Applications," *UC Berkeley Nuclear Engineering Colloquium*, 2009.

3. Tang, V., J. Morse, G. Meyer, *et al.*, "Crystal Driven Neutron Source: A New Paradigm for Miniature Neutron Sources," *AIP Conf. Proc.*, **1099**, 870, 2009.

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